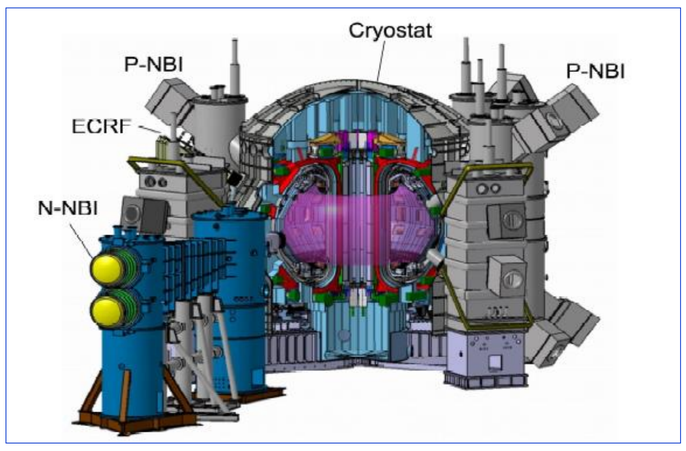
JT-60SA Toroidal Field Coils Test Cryostat Development

A collaboration between :

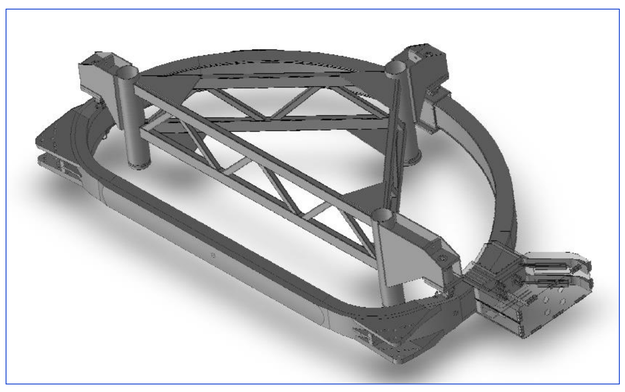
F4E Broader Fusion Development Dept., Germany
SCK/CEN, Belgium
CEA/DSM/IRFU CEA-Saclay, France
Ateliers de la Meuse (ALM), Belgium
VBTech S.A., Luxembourg

Introduction

- JT-60SA : JAEA tokamak upgraded to superconducting
  - ✓ 18 Superconducting toroidal field magnets provided by EU (9 by Italy, 9 by France)
  - ✓ Need to test all these magnets at operating conditions before delivery
- Test Cryostat developed by VBTech, CEA and ALM :
  - ✓ vacuum vessel, vacuum system, coils test support, and thermal liquid nitrogen shields by VBTech and ALM (B)
  - ✓ cryogenic system, electrical and safety system, test performance by CEA Saclay (F)



Overview JT-60SA, in red the toroidal field coils



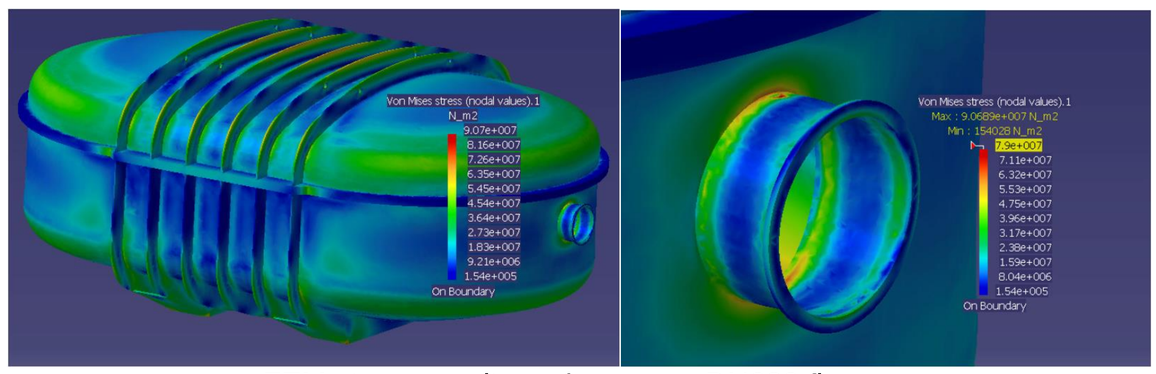
Overview of TF coil on its test adaptor

Requirements

- Operating conditions for the magnets :
  - ✓ vacuum
  - ✓ thermal load minimised by liquid nitrogen shielding
  - ✓ nominal current 25.7 [kA]
  - ✓ nominal temperature 5 [K], with temperature margin tested up to around 7.5 [K] before quench
- Mechanical configuration
  - ✓ TF coils about 8.4 [m] long, 4.5 [m] wide and 0.7 [m] high, 18 [t] weight
  - ✓ TF coils installed horizontally, hanging on a test adaptor
  - ✓ isostatic mount with thermal decoupling
  - ✓ with electrical and helium connections on one side

Design made by VBTech

- Mechanical design :
  - ✓ main vacuum chamber (11 [m] long, 7.2 [m] wide, 6.5 [m] high)
    - with horizontal flange for full opening
    - with interface for TF coil test adaptor and thermal shields
  - ✓ auxiliary vacuum chamber (Valve box, 2.2 [m] diameter, 2.5 [m] high)
    - hosting the valves, circulators, heat exchangers, electrical feeders
    - with interface to helium refrigerator and current leads
  - ✓ full FEM model (SAMCEF) for deformation and stress evaluation due to atmospheric pressure and weight
- Thermal design
  - ✓ radiation shields covering the vacuum vessel
  - ✓ electro-polished embossed stainless steel panels
  - ✓ isostatic mount with thermal decoupling
  - ✓ thermal decoupling to TF coil and LN_2 intercept for coil adaptor at vessel interface
- Vacuum design
  - ✓ large volume 400 [m^3]
  - ✓ primary vacuum to be reached in several hours
  - ✓ secondary vacuum by oil diffusion pump
  - ✓ computations with CSL software
  - ✓ 2000 [m^3 h^{-1}] rotary and 6000 [l s^{-1}] diffusion pumps



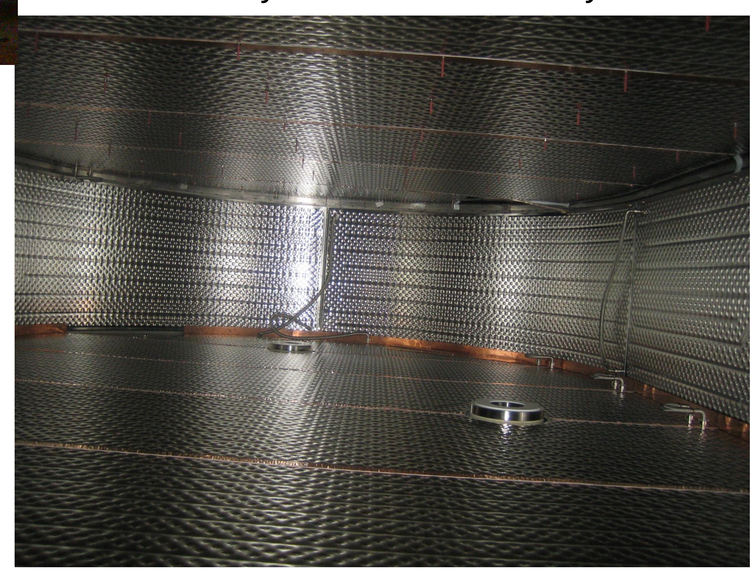
FEM stress results and zoom on DN630 flange

Machining of the main flange (see scale with operator on right)

Manufacturing

- Large parts :
  - ✓ 60 [t] assembled cryostat
  - ✓ approximate volume 400 [m^2]
- All main parts machined at ALM :
  - ✓ main vacuum vessel
  - ✓ main vacuum vessel cover
  - ✓ valve box
  - ✓ valve box cover
- Assembly of vessel, thermal shields, TF coils test adaptor and vacuum system done at ALM by VBTech

Open-close check for cover, pumping system in front



Inside the thermal shields when cover is on

Fit check of the TF coil adaptor

Test performed by VBTech

- Vacuum test :
  - ✓ for main vessel and valve box
  - ✓ integrity under atmospheric pressure load
  - ✓ evacuation time
  - ✓ ultimate pressure
  - ✓ Helium leak tests, global leak rate test (< 10^{-2} [mb l s^{-1}])
  - ✓ Helium pressure test of thermal shields up to 5 [barg]
- Ambient tests :
  - ✓ opening - closing of cover (25 [t] part)
  - ✓ installation of TF coil test frame on its isostatic mount
  - ✓ magnetic material verification

Conclusion

- Toroidal Field coils test cryostat developed by VBTech and ALM
- Mechanical, thermal and vacuum aspects requirements fulfilled successfully
- Test cryostat delivered to CEA Saclay mid September 2012
- TF coil test facility set-up done by CEA Saclay at their premises
- TF coil tests successfully done by CEA Saclay

View through side flange with adaptor